

evolution

*a journey into where we're from
and where we're going*

Chapter 22.

Evidence of Evolution by Natural Selection





Evolution is "so overwhelmingly established that it has become irrational to call it a theory."

**-- Ernst Mayr
What Evolution Is
2001**

**Professor Emeritus, Evolutionary Biology
Harvard University
(1904-2005)**

2005-2006

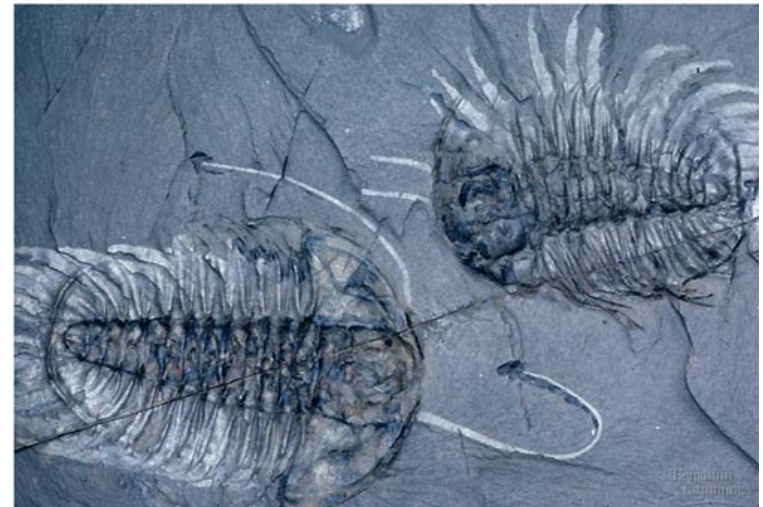


Support for Darwin's ideas

- **Fossil record**
 - ◆ change over time
- **Biogeography**
 - ◆ related organisms in similar range
- **Comparative anatomy**
- **Comparative embryology**
- **Molecular biology**
 - ◆ measure of common ancestry
- **Artificial selection**
 - ◆ induced evolution

Fossil record

- **Layers of sedimentary rock contain fossils**
 - ◆ new layers cover older ones, creating a record over time
 - ◆ fossils within layers show that a succession of organisms have populated Earth throughout a long period of time

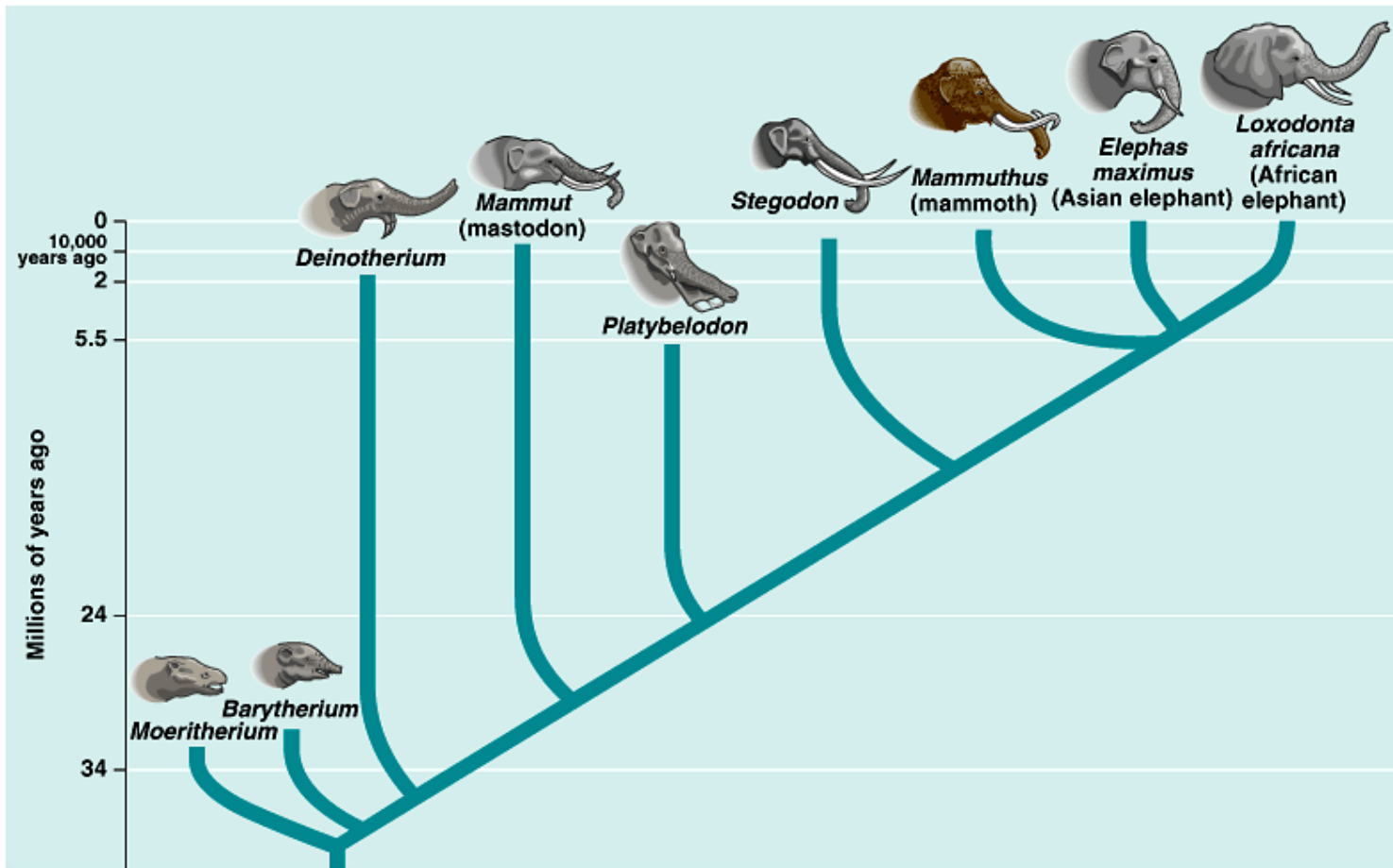


Fossil Record



Fossil record

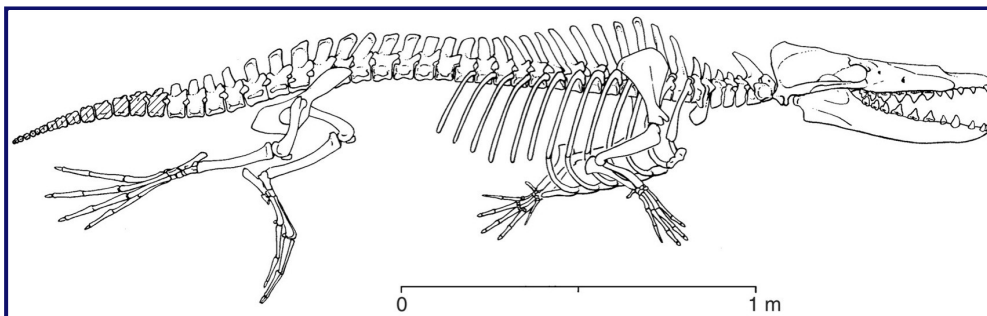
- Today's organisms descended from ancestral species



Archaeopteryx

**Fossil of
Archaeopteryx,
reptilian bird
ancestor that lived
about 150 million
years ago.**





65 60 55 50 45 40 35 30 million years ago

Paleocene

Eocene

Oligocene



Land Mammal

?

?

Where are the Intermediates?

?

?



Basilosaurus

Mysticetes



Odontocetes

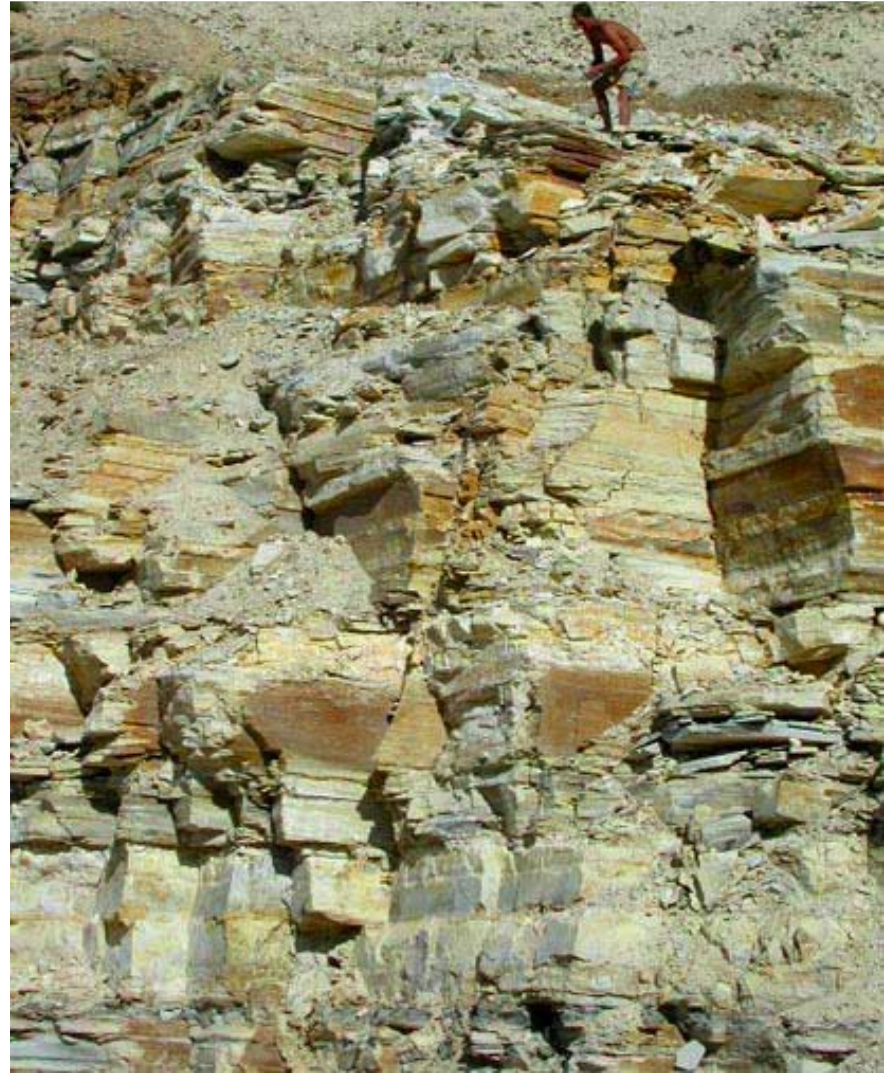
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Evolution: The Triumph of an Idea,
 by Carl Zimmer.
 New York: Harper Collins Publishers, 2001.
 Source: Art by Deborah Perugi,
 adapted from Carl Buell's
 cladogram from *At the Water's Edge*,
 by Carl Zimmer, Free Press, 1998.
 file source:
Cetacean Evolution (Whales, Porpoises, Dolphins)
 by Edward T. Babinski
http://www.edwardtbabinski.us/babinski/whale_evolution.html

Study of Paleontology

Older sediments are below younger sediments.



Georges Cuvier (1769-1832)



Gradualism

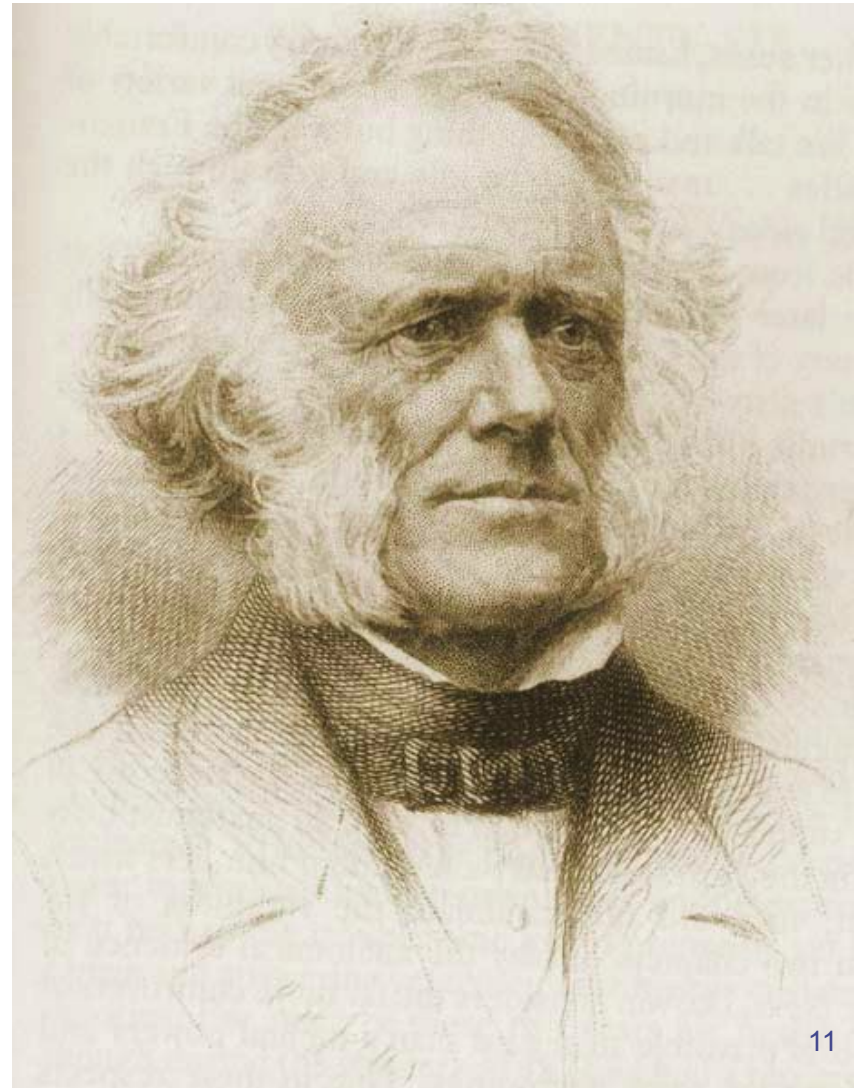
- **James Hutton (1726-1797)**
 - ◆ Earth's geologic features — profound change formed as product of slow but continuous & cumulative processes



Uniformitarianism

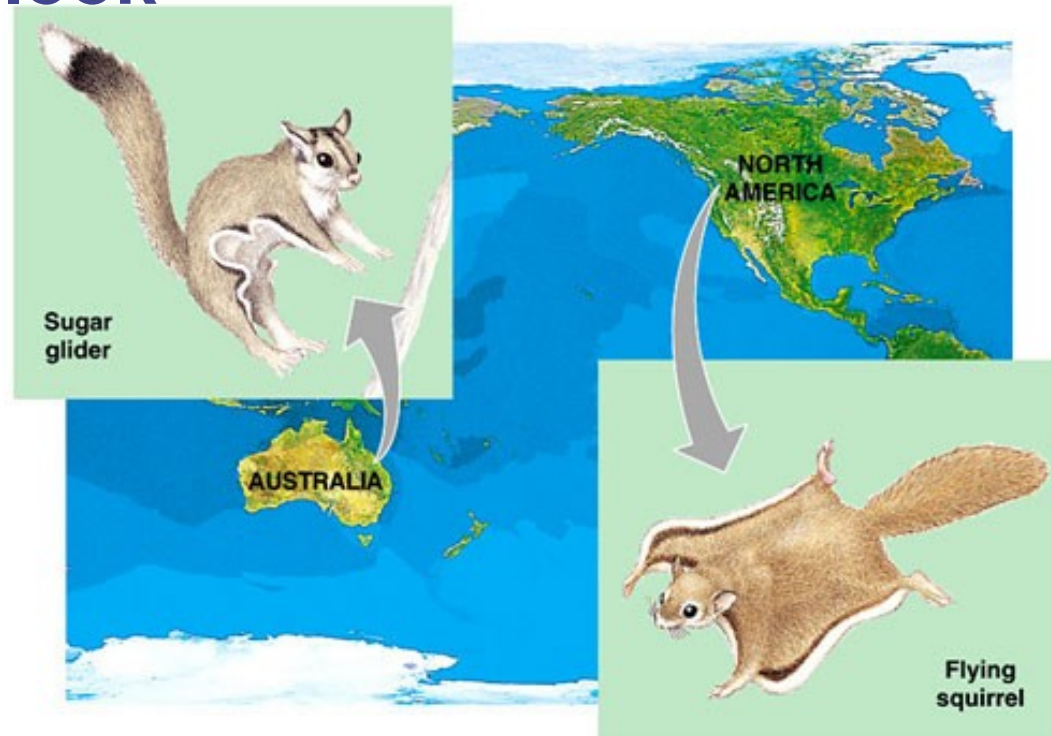
■ Charles Lyell (1797-1875)

- ◆ geologic processes have not changed throughout Earth's history
- ◆ Conclusion: Earth must be much older than 6,000 years



Biogeography

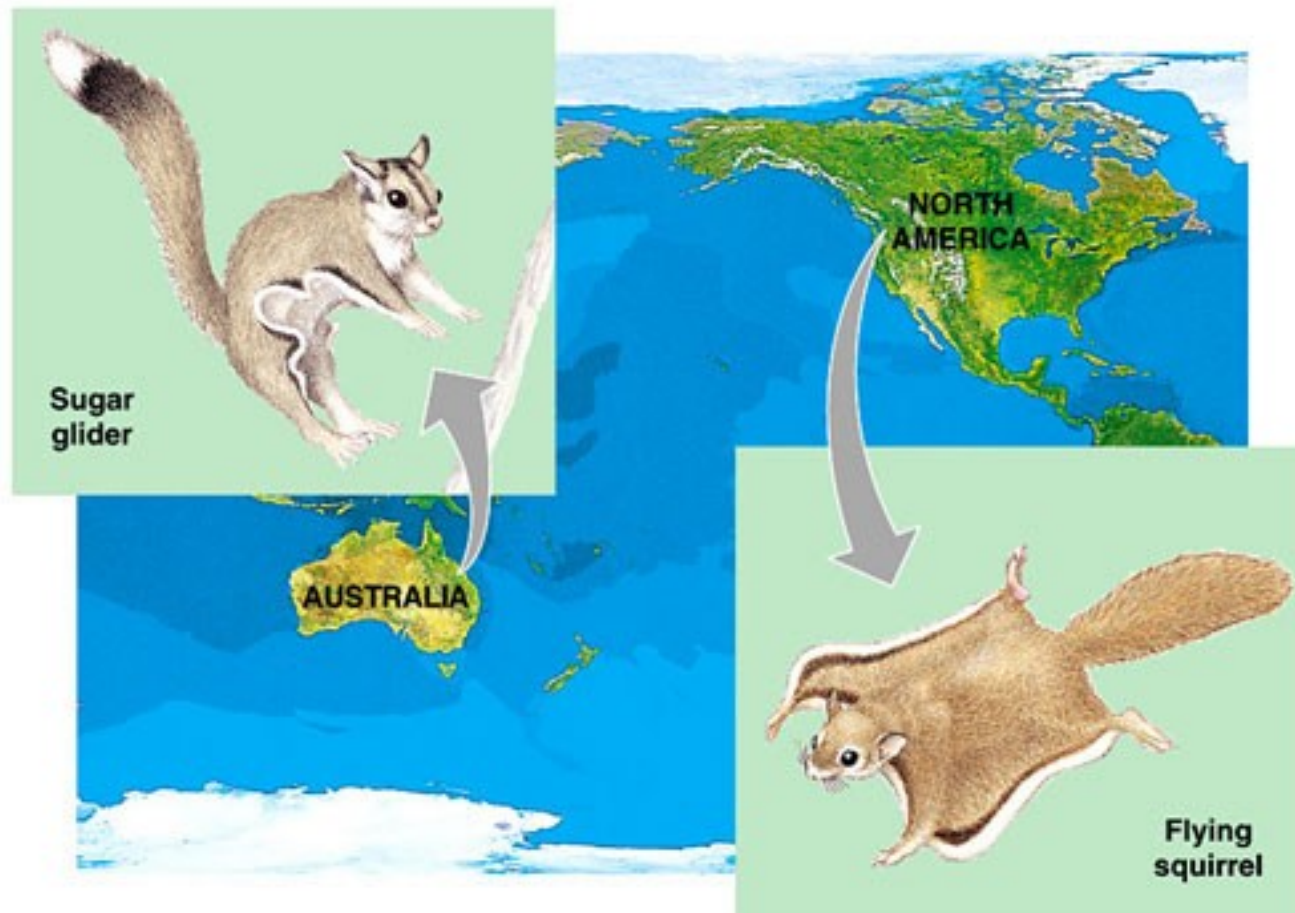
- Geographical distribution of species
 - ◆ species living in the same region tend to be more closely related to each other
 - ◆ species which look similar but are from different regions are often not closely related



Biogeography

■ Convergent evolution

- ◆ evolving similar solutions to similar “problems”



**marsupial
mammals**

vs.

**placental
mammals**

Analogous structures

- Convergent evolution of structures
 - ◆ similar functions
 - ◆ similar external form
 - ◆ different internal structure & development
 - ◆ different origin
 - ◆ no evolutionary relationship

Solving a similar problem with a similar solution

Analogous structures

- Dolphins: aquatic mammal
- Fish: aquatic vertebrate
 - ◆ have adapted to life in the sea
 - ◆ not closely related



Analogous structures

- 3 groups with wings
 - ◆ does this mean they have a recent common ancestor?

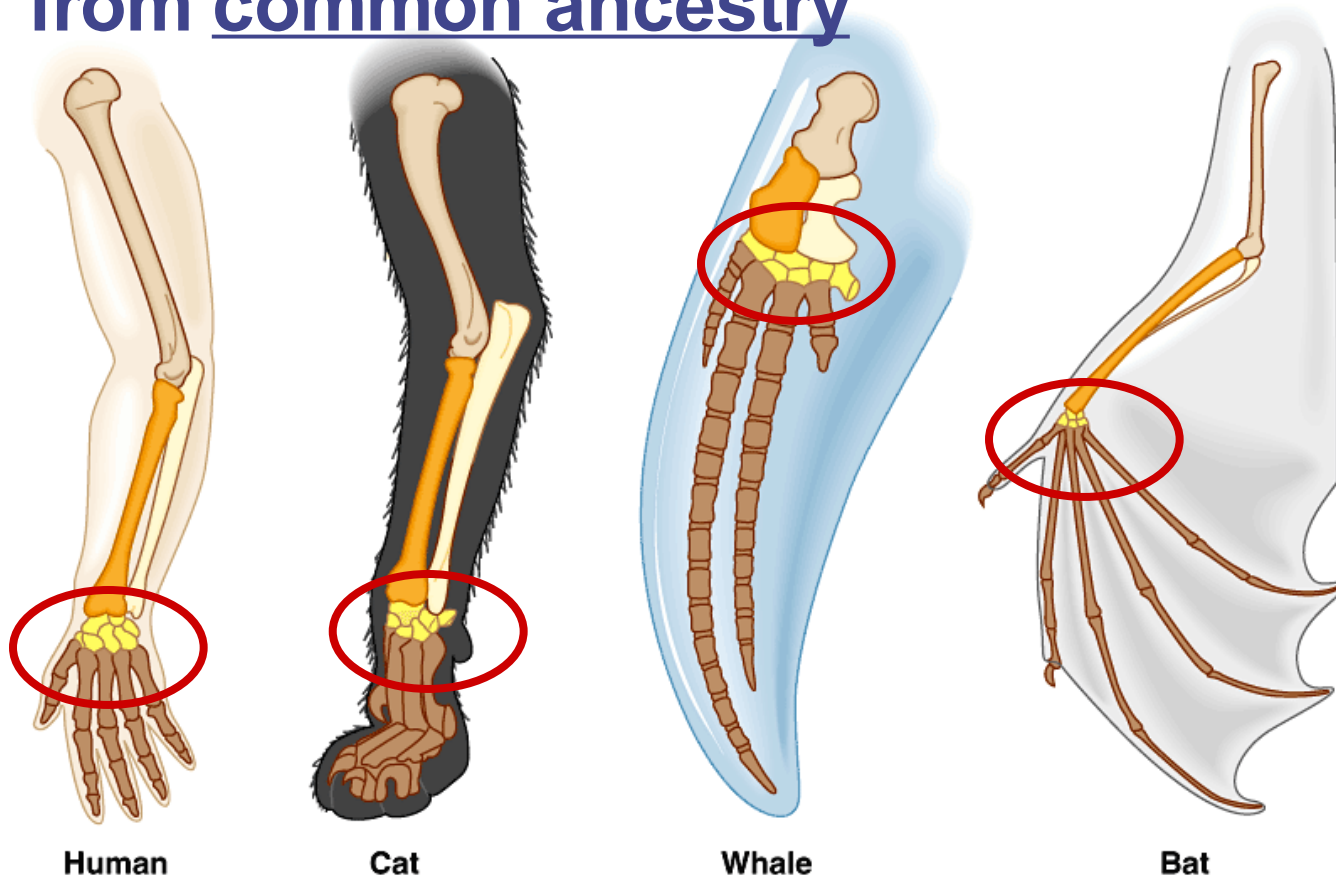
flight evolved 3
separate times =
evolving similar
solutions to similar
“problems”



Homologous structures

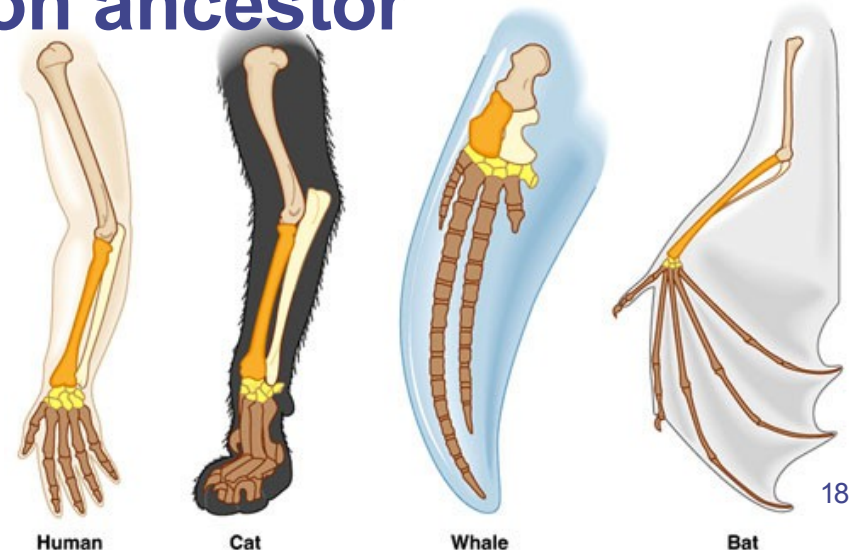
■ Homology

- ◆ similarities in characteristics resulting from common ancestry



Homologous structures

- Forelimbs of human, cats, whales, & bats share same skeletal structures
 - ◆ similar structure
 - ◆ similar embryological development
 - ◆ different functions
 - ◆ evidence of common ancestor
 - branched off from common 4-limbed ancestor



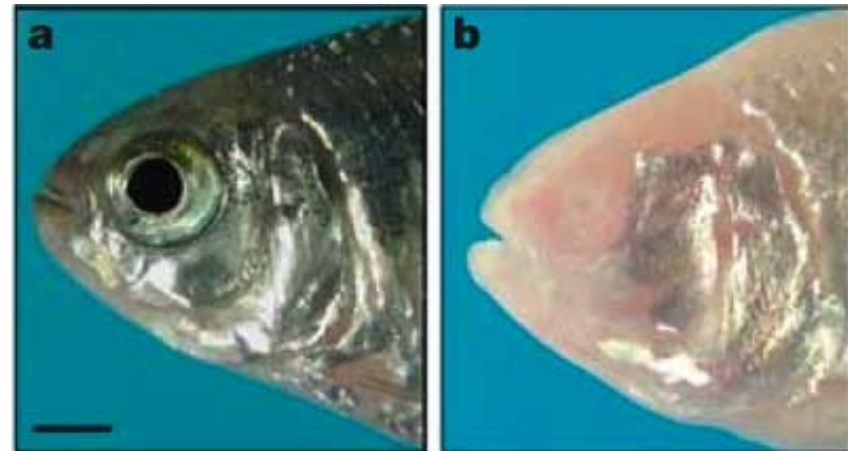
Homologous structures

- Similar structure
- Similar development
- Different functions
- Evidence of a recent common ancestor



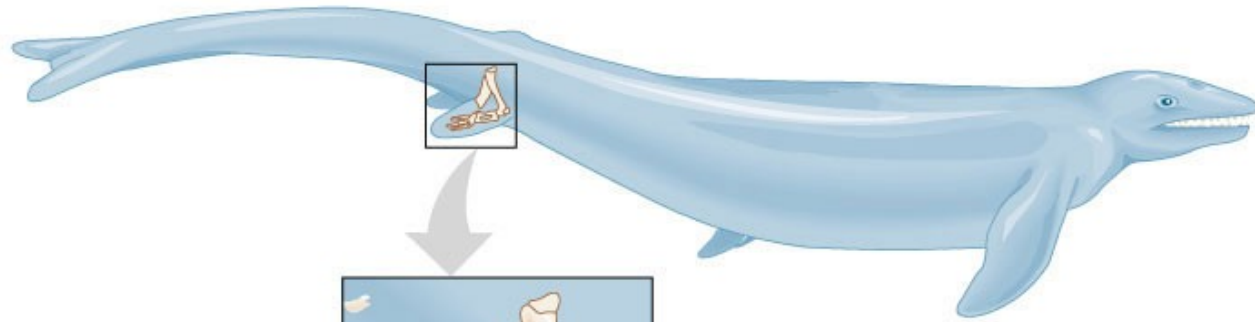
Vestigial organs

- Modern animals may have structures that serve little or no function
 - ◆ remnants of structures that were functional in ancestral species
 - ◆ evidence of change over time
 - some snakes & whales show remains of the pelvis & leg bones of walking ancestors
 - eyes on blind cave fish
 - human tail bone



Vestigial organs

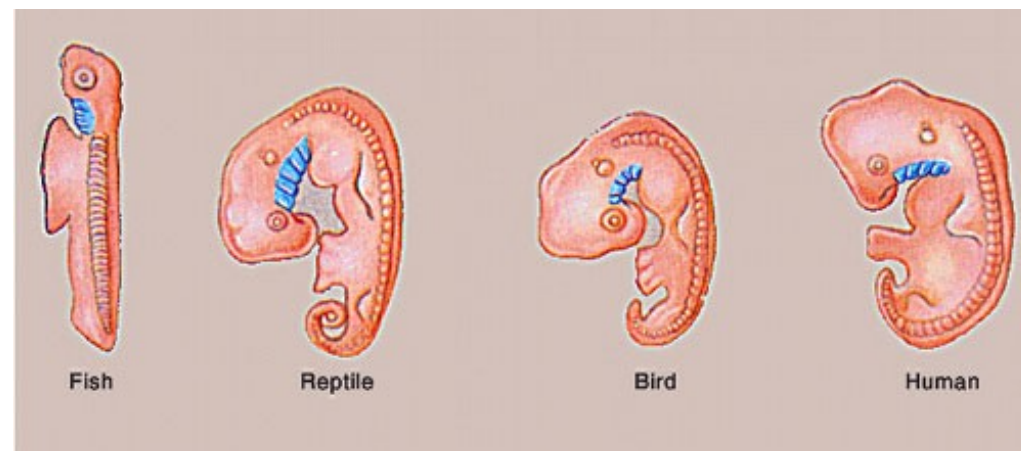
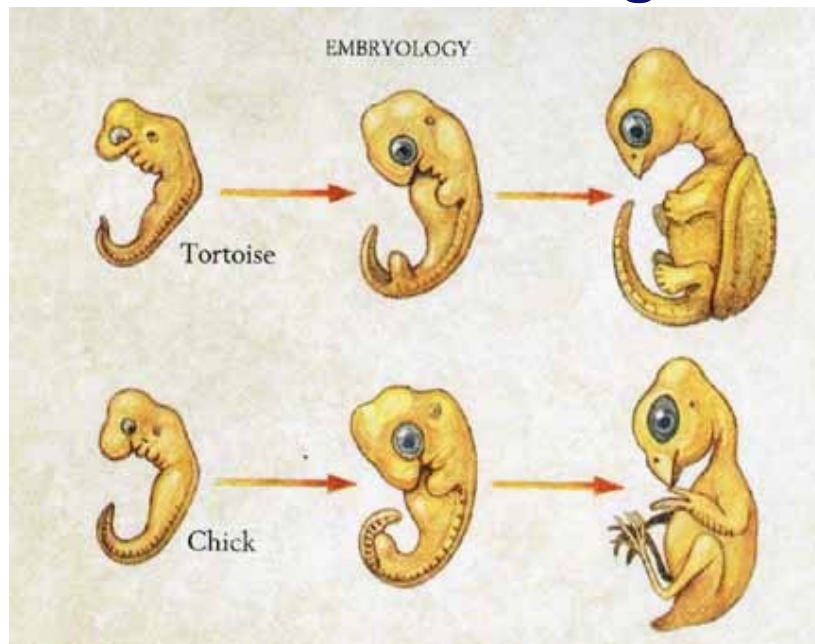
- Hind leg bones on whale fossils



Why would whales have pelvis & leg bones if they were always sea creatures?

Comparative embryology

- Similar embryological development in closely related species
 - ◆ all vertebrate embryos have a gill pouch at one stage of development
 - fish, frog, snake, birds, human, etc.



Molecular biology

- **Comparing DNA & protein structure**
 - ◆ **universal genetic code!**
 - **DNA & RNA**
 - ◆ **cytochrome C (respiration)**
 - **protein structure**
 - ◆ **hemoglobin (gas exchange)**
 - **protein structure**

Evolutionary relationships among species are documented in their DNA & proteins.

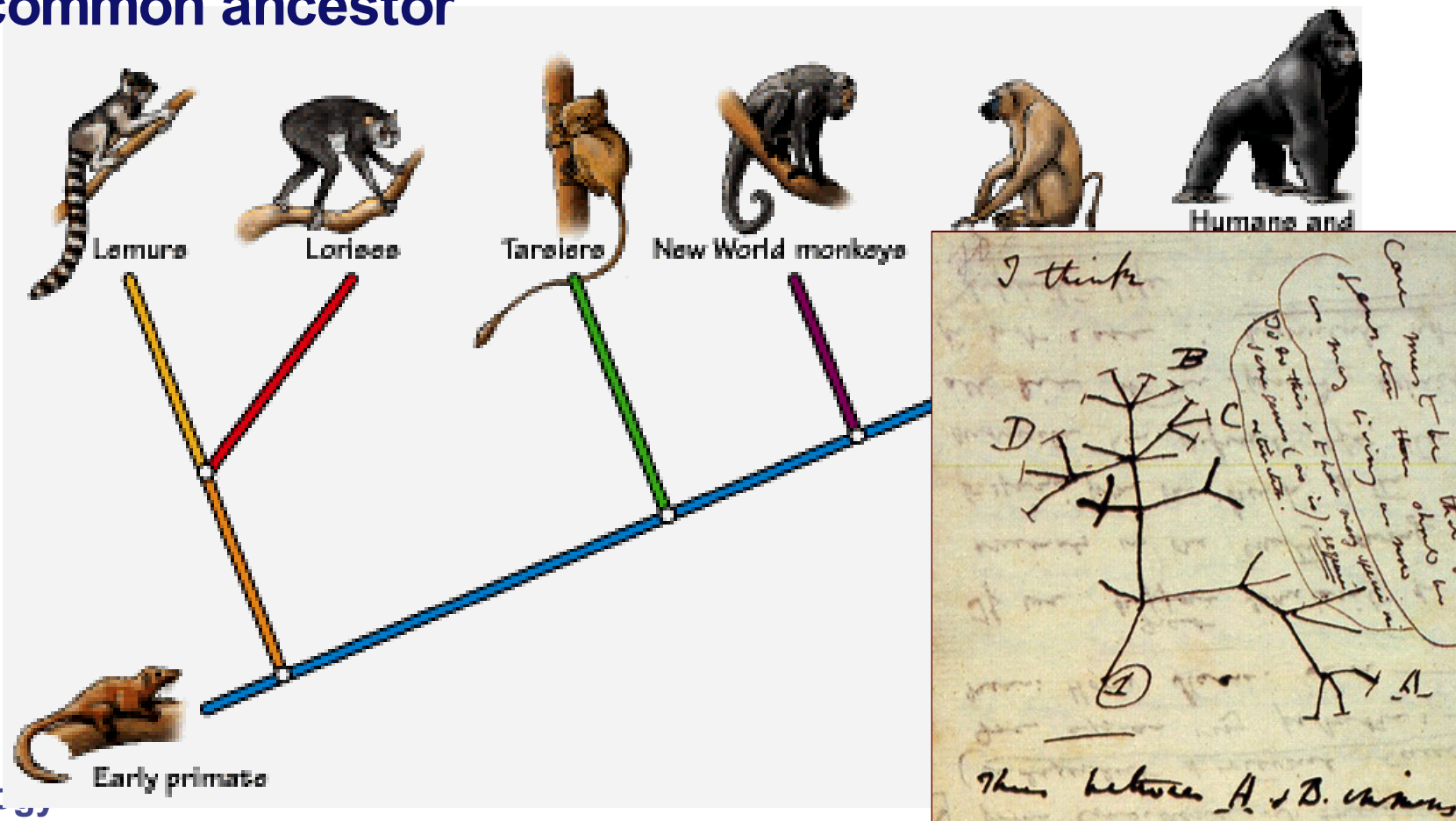
Closely related species have sequences that are more similar than distantly related species.

Comparative hemoglobin structure

QuickTime™ and a
GIF decompressor
are needed to see this picture.

Building “family” trees

Closely related species (twigs of tree) share same line of descent until their recent divergence from a common ancestor



What data from whole genome sequencing can tell us about evolution of humans

Chimp genetic code opens human frontiers

Genome comparison reveals many similarities — and crucial differences

By Alan Boyle

Science editor

MSNBC

Updated: 4:20 p.m. ET Sept. 1, 2005

Scientists unleashed a torrent of studies comparing the genetic coding for humans and chimpanzees on Wednesday, reporting that 96 percent of our DNA sequences are identical. Even more intriguingly, the other 4 percent appears to contain clues to how we became different from our closest relatives in the animal kingdom, they said.

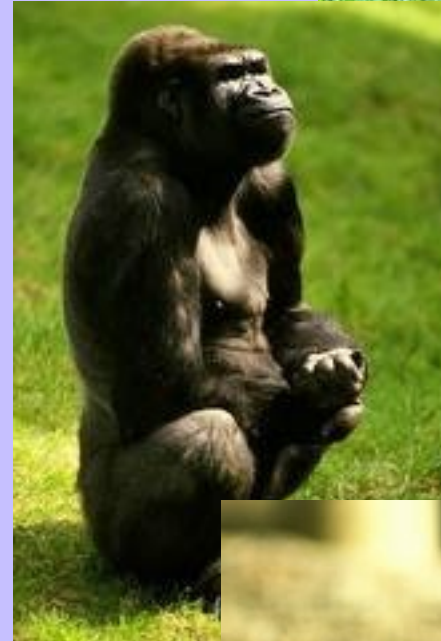
"We're really looking at an individual evolutionary event, and this is spectacular," said University of Washington geneticist Robert Waterston, senior author of a study in the journal *Nature* presenting the draft of the chimpanzee genome.



Example: the Evolutionary Hypothesis of Common Ancestry

Chromosome Numbers in the great apes:

human (<i>Homo</i>)	46 ←
chimpanzee (<i>Pan</i>)	48
gorilla (<i>Gorilla</i>)	48
orangutan (<i>Pongo</i>)	48

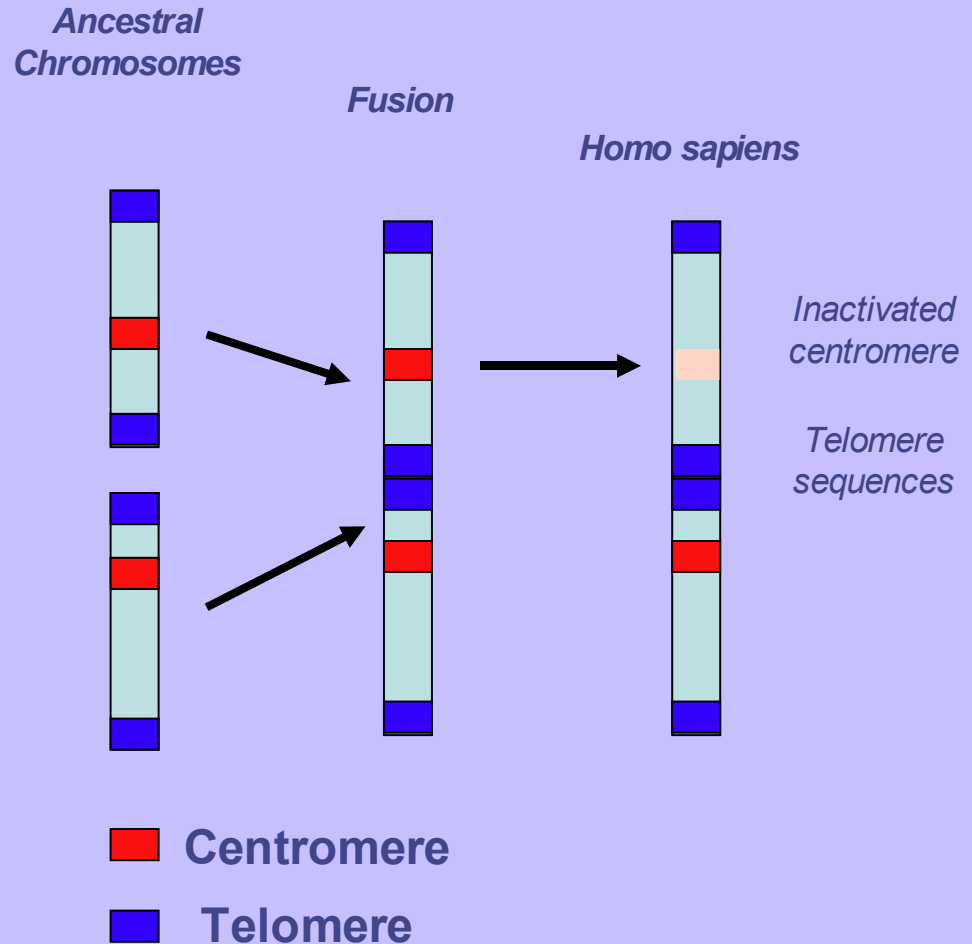


Testable prediction:

If these organisms share a common ancestor, that ancestor had either 48 chromosomes (24 pairs) or 46 (23 pairs).

Chromosome Numbers in the great apes (*Hominidae*):

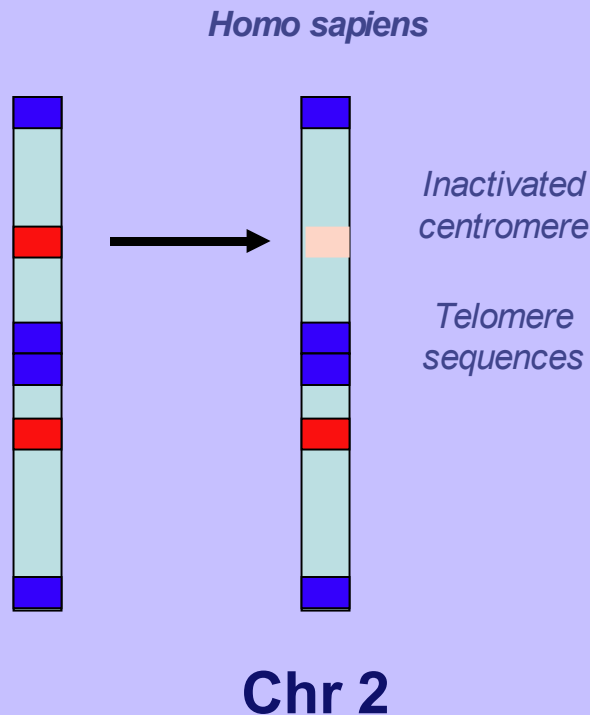
human (<i>Homo</i>)	46
chimpanzee (<i>Pan</i>)	48
gorilla (<i>Gorilla</i>)	48
orangutan (<i>Pongo</i>)	48



Testable prediction:

Common ancestor had 48 chromosomes (24 pairs) and humans carry a fused chromosome; or ancestor had 23 pairs, and apes carry a split chromosome.

Human Chromosome #2 shows the exact point at which this fusion took place



“Chromosome 2 is unique to the human lineage of evolution, having emerged as a result of head-to-head fusion of two acrocentric chromosomes that remained separate in other primates. The precise fusion site has been located in 2q13–2q14.1 (ref. 2; hg 16:114455823 – 114455838), where our analysis confirmed the presence of multiple subtelomeric duplications to chromosomes 1, 5, 8, 9, 10, 12, 19, 21 and 22 (Fig. 3; Supplementary Fig. 3a, region A). During the formation of human chromosome 2, one of the two centromeres became inactivated (2q21, which corresponds to the centromere from chimp chromosome 13) and the centromeric structure quickly deteriorated (42).”

Hillier *et al* (2005) “Generation and Annotation of the DNA sequences of human chromosomes 2 and 4,” *Nature* 434: 724 – 731.



Artificial selection

- Artificial breeding can use differences between individuals to create vastly different “breeds” & “varieties”



“descendants” of wild mustard

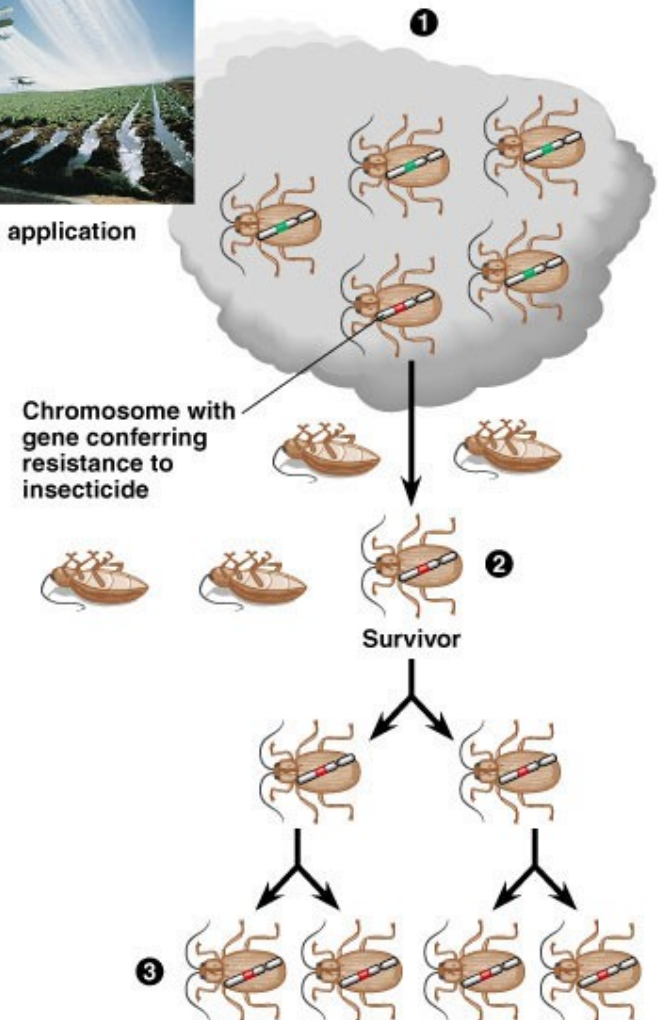
“descendants” of the wolf

Natural selection in action

- Insecticide & drug resistance
 - ◆ insecticide didn't kill all individuals
 - ◆ resistant survivors reproduce
 - ◆ resistance is inherited
 - ◆ insecticide becomes less & less effective



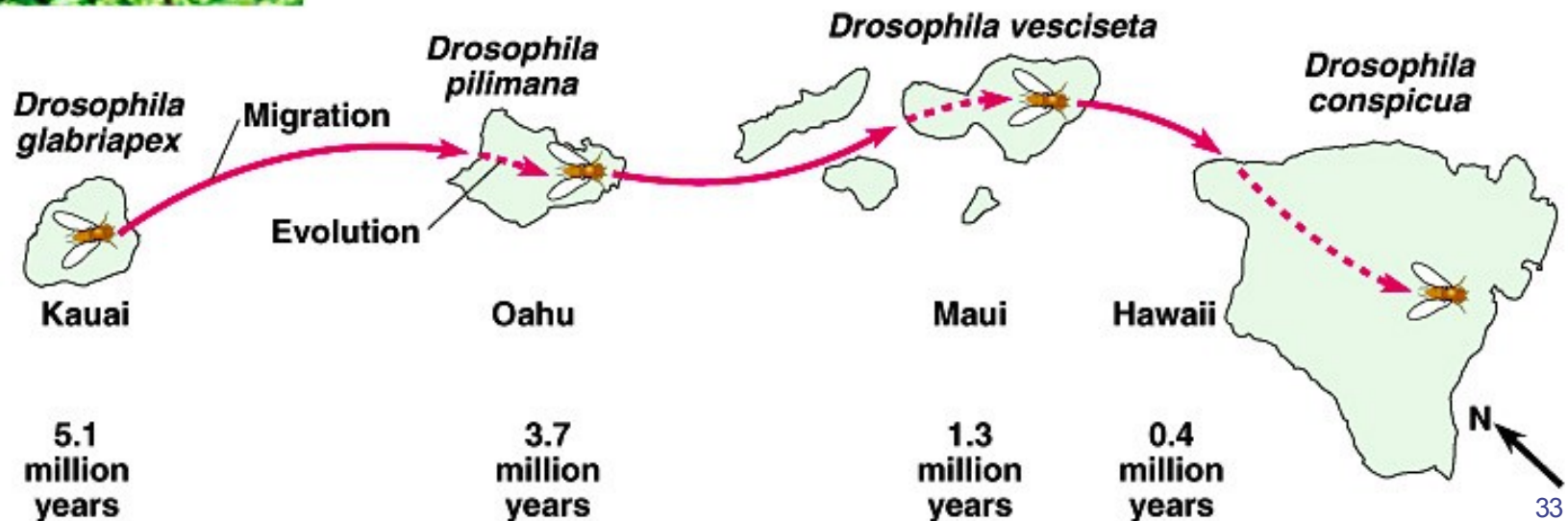
Insecticide application



Evolution of *Drosophila*

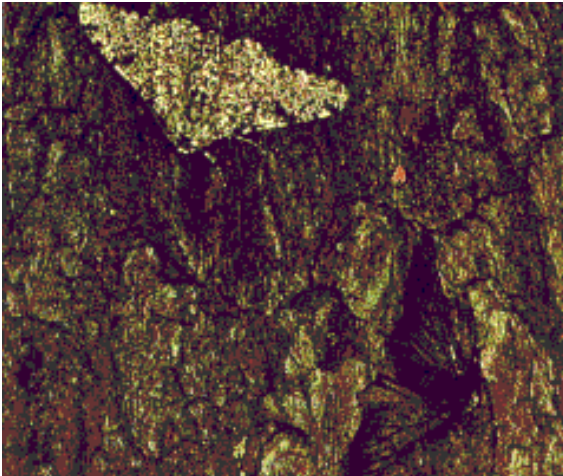


All of the 500+ endemic species of *Drosophila* in Hawaiian archipelago descended from common ancestor that reached Kauai over 5 million years ago



Witness to Evolution

- **Peppered Moth**
 - ◆ dark vs. light variants



Peppered moth

Peppered moth

<u>Year</u>	<u>% dark</u>	<u>% light</u>
1848	5	95
1895	98	2
1995	19	81



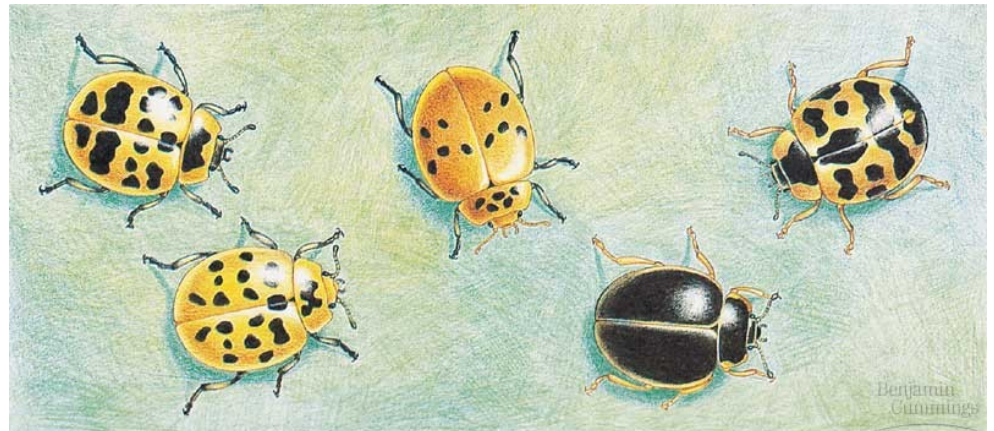
Peppered moth

- Why did the population change?
 - ◆ early 1800s = pre-industrial England
 - low pollution
 - lichen growing on trees = light colored bark
 - ◆ late 1800s = industrial England
 - factories = soot coated trees
 - killed lichen = dark colored bark
 - ◆ mid 1900s = pollution controls
 - clean air laws
 - return of lichen = light colored bark

◆ **industrial melanism**

Unity & Diversity

- Only evolution explains both the unity & diversity of life
- By attributing the diversity of life to natural causes rather than to supernatural creation, Darwin gave biology a strong, scientific, testable foundation





Any Questions??